
Chapter 12

Automation in Quality Control

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1. INTRODUCTION	414
2. CENTRALISED CONTROL SYSTEMS	415
2.1 The Automated Control System at Obourg (Lit. 1).....	415
2.2 The Control Concept at Gmunden (Lit. 2).....	421
3. DECENTRALISED CONTROL SYSTEMS	423
3.1 Raw Meal Control at Altkirch	423
3.2 Clinker Control.....	425
3.3 Physical Cement Testing	429
4. BULK MATERIAL CONTROL BY NEUTRON ACTIVATION ANALYSIS.....	429

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Automation in Quality Control

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Summary:

Automated quality control systems find increasing application in the cement industry. The main objectives are to intensify the control in order to achieve more uniform materials properties and to reduce risks associated with inadequate quality and to reduce shift personnel in quality control. Automated systems are widely applied for raw mix blending and clinker control, to a lesser extent so far on cement grinding, and little for physical cement testing.

The paper reviews the concept and main features of such systems on the hand of examples mainly from 'Holderbank' group plants, and briefly discusses the potential and limits of neutron activation analysis.

Report No. MA 89/3702/E

1. INTRODUCTION

There is definitely a trend to increase the automation in quality control procedures in the cement industry, whereby the degree of automation can vary from individual automated testing equipment to complex integrated on-line systems.

The objectives of automation, and possible drawbacks are summarised in the following figure.

Fig. 1 BENEFITS AND DRAWBACKS OF AUTOMATED CONTROL SYSTEMS

BENEFITS:

Increased product quality and reduced operation costs through improved uniformity:

- ◆ high sampling frequency
- ◆ more sampling points
- ◆ round-the-clock control
- ◆ optional on-line link to process computer
- ◆ high standard of sample preparation and analysis
- ◆ elimination of operator related errors

Liberation of personnel from routine work for more demanding duties.

Reduction of personnel.

DRAWBACKS:

High investment costs

Susceptible to (minor) technical faults

Requirement of back-up methods

Highly qualified personnel required for maintenance

An attempt to classify various concepts of automation is made in Figure 2.

FIG. 2 CONCEPTS OF AUTOMATED CONTROL SYSTEMS

◆ Centralised:

- sample transport to central test laboratory

◆ Decentralised:

- sample transport to testing equipment installed close to production unit
- continuous analysis on full or partial, by-passed materials stream

The present paper does not aim at giving a systematic, well balanced review of current automation systems, but to highlight some selected aspects of automation, mainly taken from examples of such systems installed in Holderbank Group plants.

2. CENTRALISED CONTROL SYSTEMS

2.1 The Automated Control System at Obourg (Lit. 1)

2.1.1 Objective

Obourg is one of the few remaining wet plants in western Europe. The tradition of using low-cost ash rich coal has made it possible to produce at costs competitive to dry plants. The lay-out is shown in Figure 3.

The diagram illustrates the production process of cement, divided into two main stages: Slurry preparation and Clinker formation.

Slurry preparation stage:

- Inputs:** Clay and Slurry (represented by triangles) are fed into "Dil. + vat" units.
- Intermediate Processing:** The output from the "Dil. + vat" units goes to a "conc. + dil." unit, which also receives input from a "chalk" source (represented by a boat).
- Basins:** The mixture is then distributed into four basins: Basin 1, B 2, B 3, and Finished slurry basin 5.

Clinker formation stage:

- Feed Silos:** The slurry from the basins is fed into silos labeled 60, 45, 45, and 60.
- Kilns:** The material enters KILN 9 and KILN 10. KILN 9 produces "Clinker", and KILN 10 produces "To cement".
- Separation and Storage:** The output from the kilns is processed through "Dust.", "LD slag", "schlamm 45", and "schl. 60" units.
- Final Processing:** The material is then processed through "Screen", "Crush.", and "COBEX" units.
- Outputs:** The final products are "sawdust", "slag", "schlamm 45", and "schlamm 60".

Additional Information:

- A "waste liquid fuel" source (represented by a boat) is shown at the bottom left, feeding into the "Screen" unit.
- The diagram is labeled "Slurry preparation" and "Clinker formation" on the right side.

The reasons for investing into a complex automated control system were:

- ◆ High variability in chemical composition; occasional quality problems due to excessive C_3A content.
- ◆ Intention to increase the use of ash rich coal, aiming at an ash content in clinker of 20% (including non-combustible components injected into the sinter zone), which increases the average C_3A content.
 - Clinker targets:
 - LS : 98 ± 1
 - C_3A : 12 ± 1 %
 - C_4AF : 11.5 ± 1 %

Such an extreme clinker composition does not tolerate significant fluctuations!

- ◆ Intention to change the slurry preparation from a batch to a continuous mode, to eliminate frequent bottlenecks in slurry production.

The realisation of these objectives necessitates very close blending control for both slurry and clinker production. After a detailed evaluation, it was decided:

- ◆ to automate slurry and clinker control up to the stage of calculation of feed corrections (excluding feeder adjustments)
- ◆ to adopt a centralised concept
- ◆ to realise the investment as a turnkey project.

A corresponding contract was made with Polysius to supply their POLAB-system, whereby detailed guarantee conditions for system performance and availability were agreed upon.

2.1.2 Aspects of hardware

Fig. 4 **Block Diagram of the Polab system.**

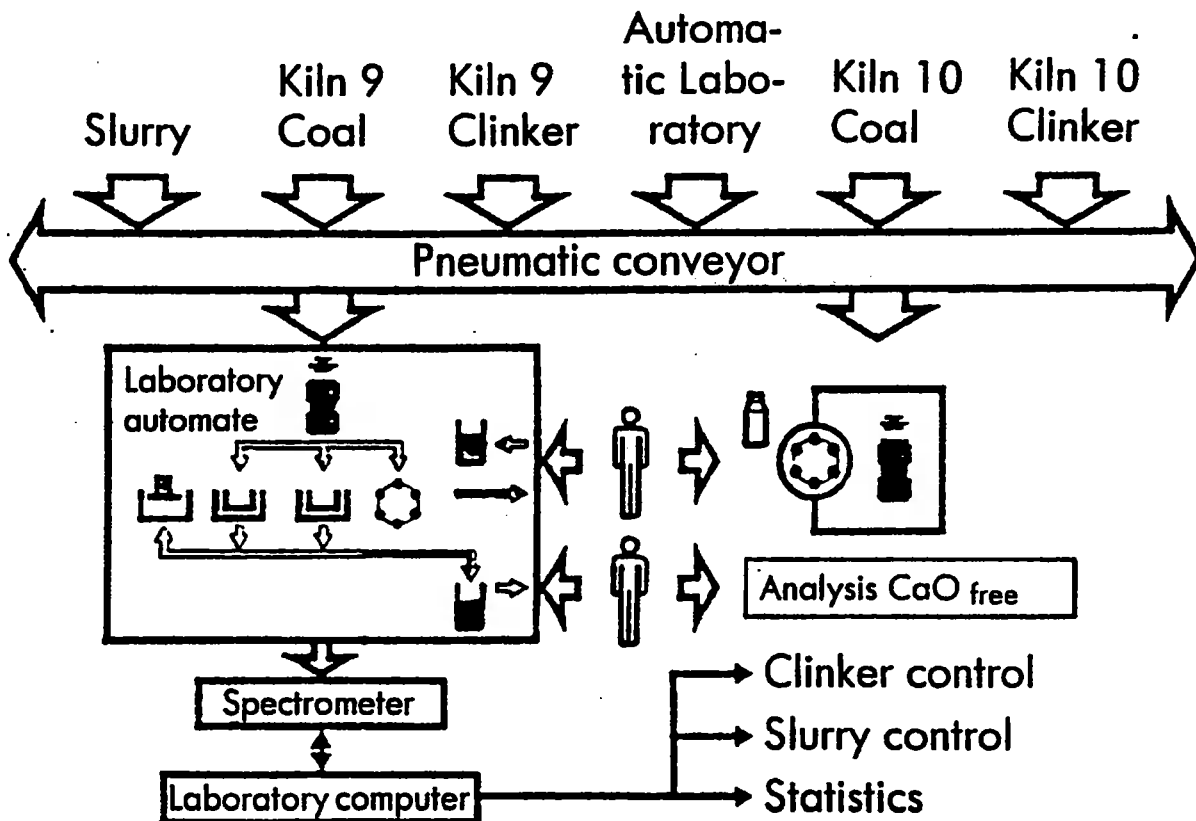
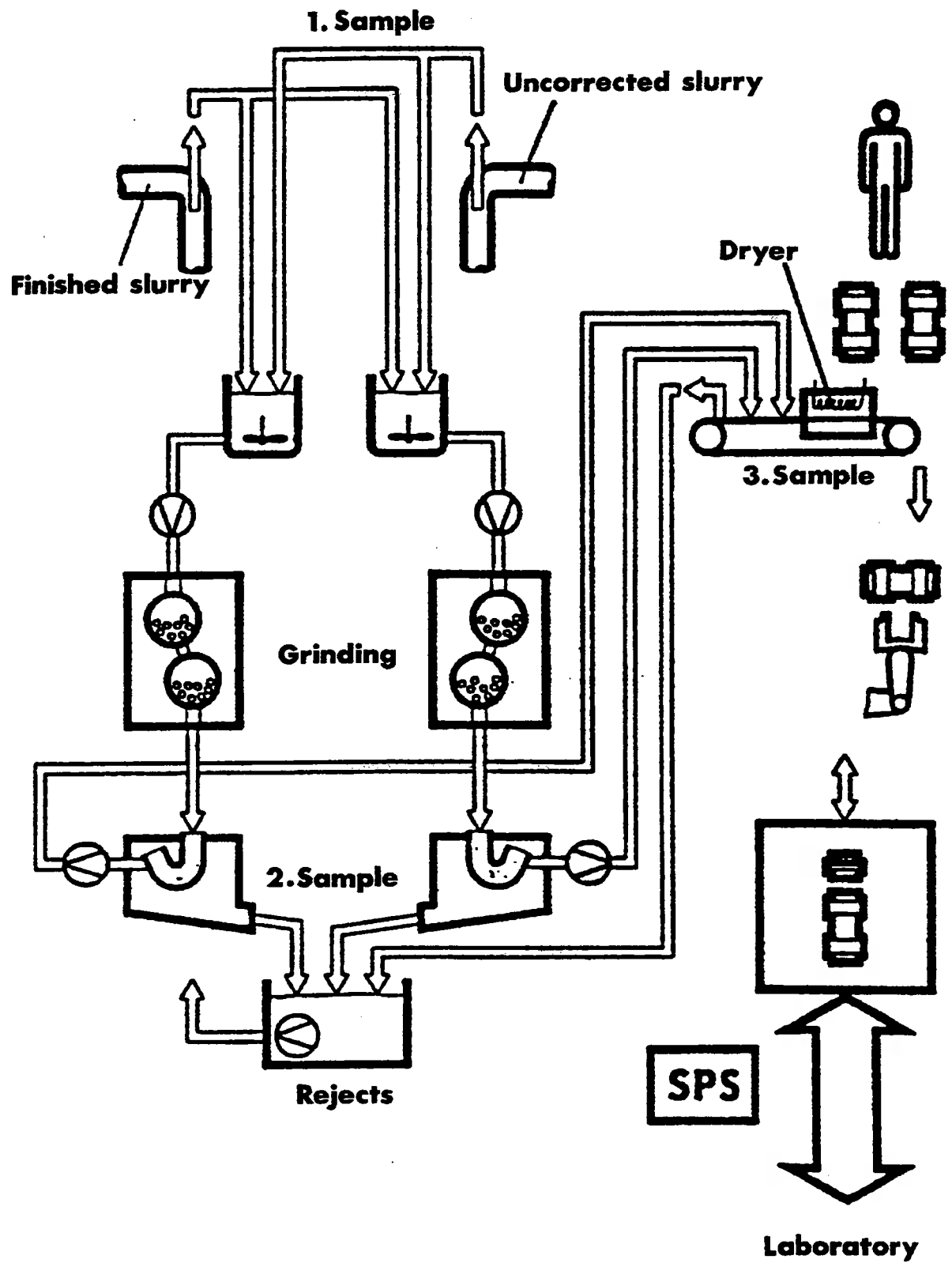


Figure 4 shows the elements of the POLAB system. Features of particular interest are:

- ◆ Slurry sampling (Figure 5)
 Emphasis was given to obtaining a representative sample of the slurry, which still contains an appreciable quantity of large grains; hence the complex preparation plant.
- ◆ Clinker sampling
 The sampling from the cooler (second screen plate) reduces the dead time of the control loop.
- ◆ Laboratory automate
 Sample preparation by grinding and pelletising was selected, one reason being the scarce experience available at that time with automated fused lead preparation.
- ◆ XRF-spectrometer
 The eight channel simultaneous spectrometer is exclusively used for the POLAB system.
- ◆ Free lime analyser
 The POLAB is complemented with a free lime analyser DIA 2000 (ethylene glycol extraction method), which was formerly installed at the kilns.

Fig. 5 Slurry sampling and preparation plant.



2.1.3 Aspects of software

The POLAB blending control software is responsible for calculating the components feed rate both for slurry preparation and for clinker production.

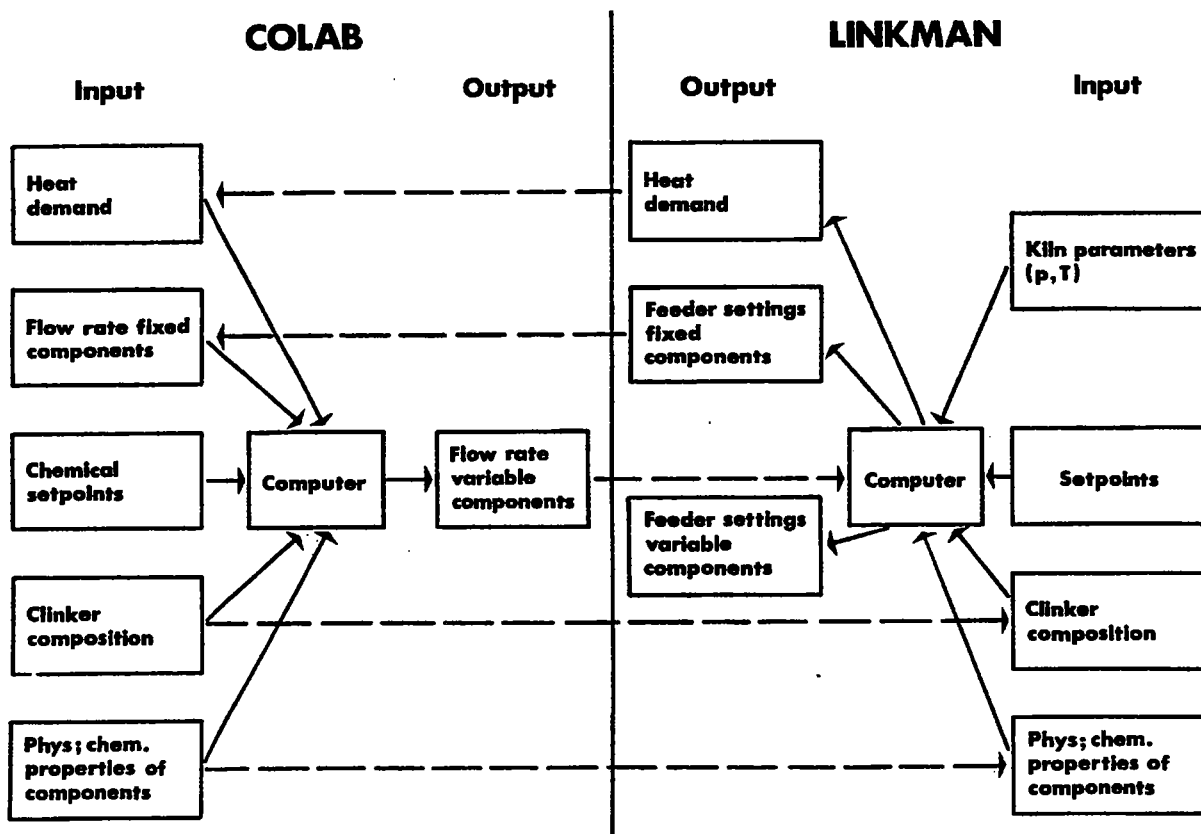
One aspect of the clinker 'blending' control is worth commenting on:

A number of the 4 or more components injected at the kiln hood into the sinter zone affect both the ash and the heat input. The blending control has therefore not only to meet the clinker composition targets, but also the target of the kiln heat requirement. The latter is introduced and continuously adapted by the kiln operator through a terminal in the control room.

2.1.4 Link to kiln automation

Recently, LINKMAN kiln automation systems were implemented for both kilns. The essential tasks of the system are to determine the kiln heat requirement and to control and automatically adjust the feed rates of all materials fed to the kiln. Because the POLAB and the LINKMAN have obviously to fulfill complementary tasks, the two respective suppliers were obliged to establish a link between these systems, with the aim of having an integrated kiln automation, simultaneously fulfilling set points for kiln operation and clinker composition. Figure 6 illustrates, in a simplified way, the concept of data exchange between the two systems.

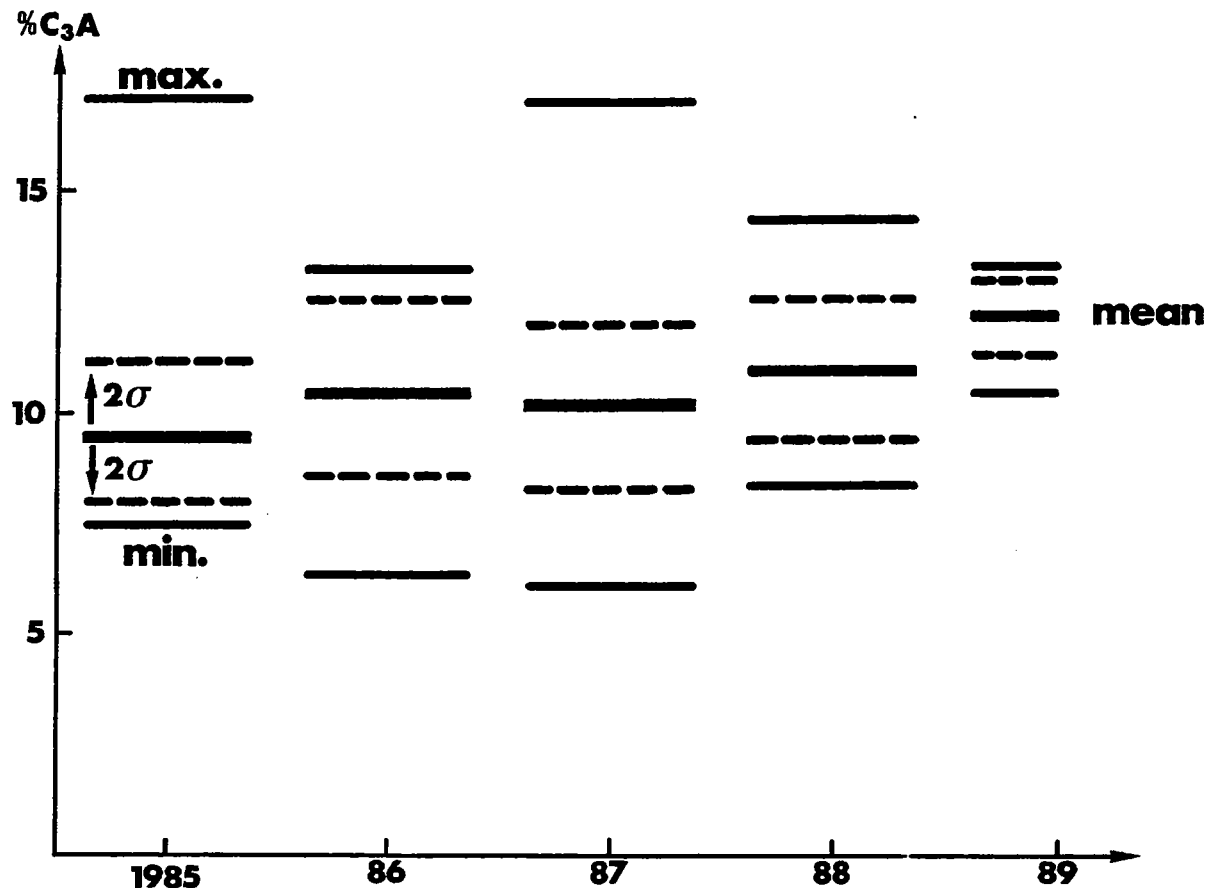
Fig. 6 Link of COLAB and LINKMAN



The link has been in successful operation since October 1989.

2.1.5 Experiences with the POLAB

Fig. 7 C₃A: Daily Mean Sample.



The experiences can be summarised as follows:

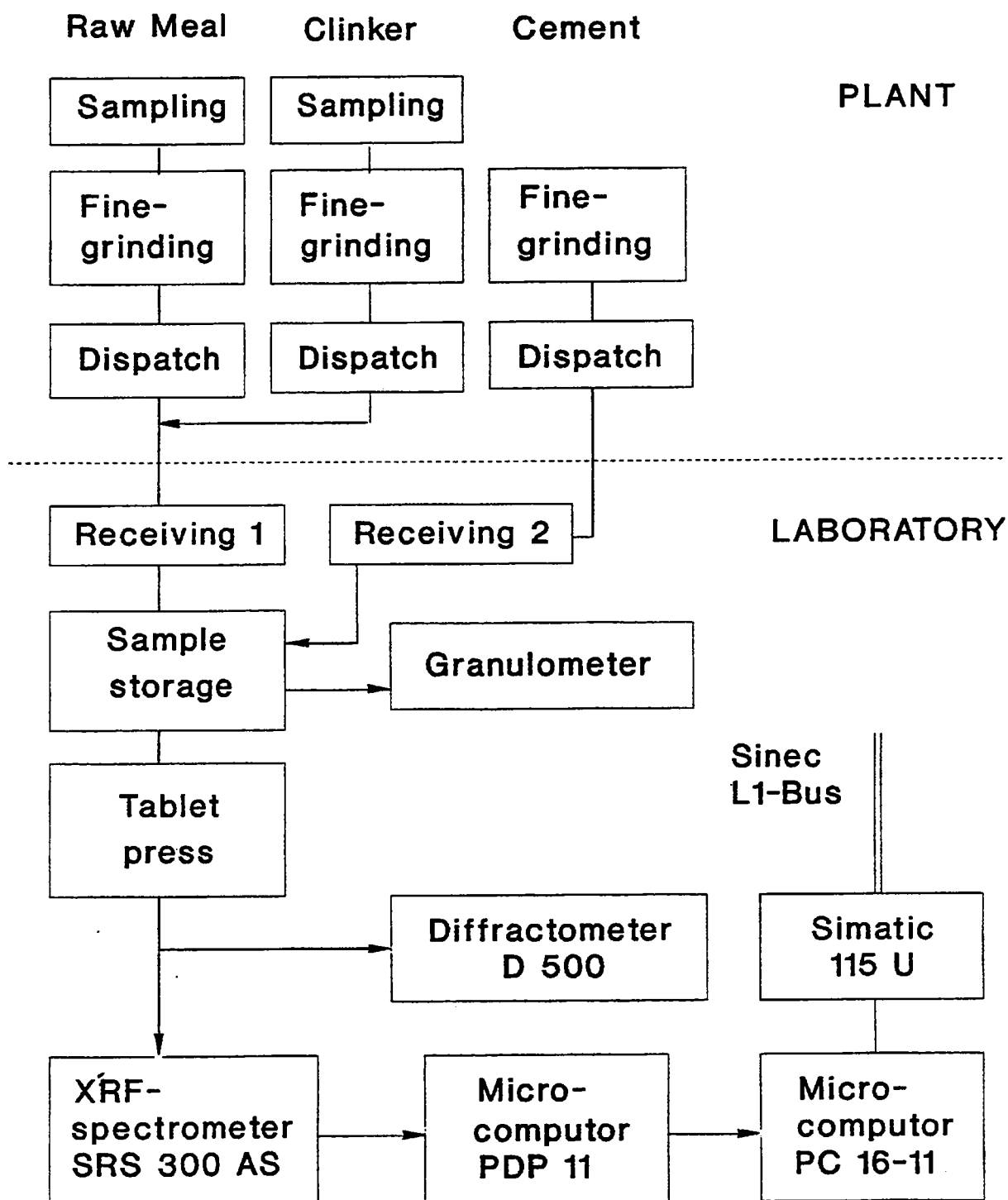
- ◆ The ash content in clinker could be raised close to 20%.
- ◆ The clinker uniformity could be significantly improved; C₃A can be controlled within + 1%, as compared to previous +3% (see Figure 7).
- ◆ The slurry preparation and control concept are successful; production bottlenecks are eliminated. On-line control of the components flow rate is anticipated.
- ◆ The K₂O-content of clinker turned out to be a rapid and significant indicator of the burning degree.
- ◆ Technical difficulties, mainly in the sector of slurry sampling and preparation - causing delay in commissioning - could be solved in a co-operative manner.
- ◆ The guaranteed systems availability of 95% could eventually be met.
- ◆ The formation of personnel to operate and maintain the system became far more demanding and time consuming than envisaged. Preventive maintenance and rapid trouble-shooting are essential to achieve and maintain the required high availability.

2.2 The Control Concept at Gmunden (Lit. 2)

The automation system at the Hans Hatschek cement plant at Gmunden, Austria, was supplied by Siemens (with Pfaff and Herzog as subcontractors). It will integrate the raw meal (already realised), clinker and cement control in three stages.

The concept is shown in Figure 8 (simplified)

Fig. 8 Automatic Concept (Gmunder Zementwerke Hans Hatschek)



In comparison to the system at Obourg, the following aspects are worth commenting.

- ◆ The sample fine-grinding is done at the place of sampling. Advantages: no bottlenecks in sample preparation in the central laboratory; less risk of sample contamination. Both untreated (for fineness determination) and fine ground samples are sent to the laboratory.
- ◆ The sequential XRF-spectrometer is also used for general analytical purposes. The software ensures that samples arriving automatically are given priority over manually introduced samples.
- ◆ The clinker free lime will be determined by X-ray diffraction, on samples prepared in the same way as for XRF-analysis.
- ◆ The future automated cement control shall include the following control parameters:
 - Fineness
Presently evaluated alternatives are:
 - * Automated Blaine-metre, AB500 by Pragoinvest, Czechoslovakia
 - * Laser-Granulometer, either with wet-dispensing system (e.g. CILAS) or dry dispensing system (e.g. Sympatec). The former would necessitate recuperation of ethanol.
 - A major criteria will be the correlation between possible fineness parameters (Blaine, size fraction) and standard mortar strength.
- ◆ Chemical composition by XRF-analysis. In addition to SO₃ determination for gypsum dosage, the determination of additional guide-elements for fly-ash and slag proportioning is anticipated.

3. DECENTRALISED CONTROL SYSTEMS

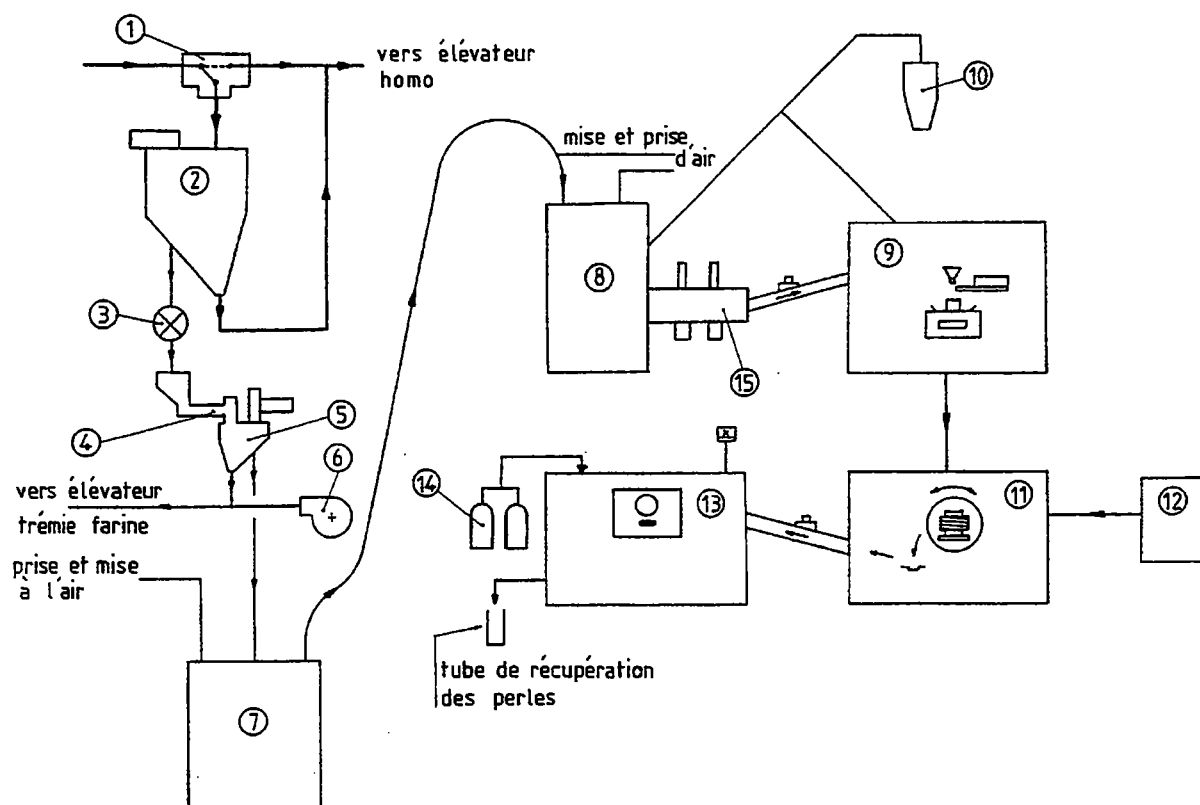
3.1 Raw Meal Control at Altkirch

Until recently, on-line raw meal control was carried out by means of an XEG (X-ray emission gauge) system installed at the exit of the raw mill. The raw meal composition was continuously determined by XRF-analysis directly on a by-passed stream of raw meal.

As the analytical accuracy has always been affected by matrix effects due to the fluctuating quartz content in the raw meal, one requirement for the necessary replacement of the system was to include conventional XRF-spectroscopy on fused beads. For reasons related to the plant layout, the new system should again be installed close to the raw mill, accepting the risks associated with a very limited systems supervision.

The new on-line control system was supplied as a turnkey project by Phillips France (Figure 9).

Fig. 9 Ciments D'Origny



Rep	Désignation	Fournisseurs
1	Vanne de dérivation	KIVAIR
2	Qualdoris 30	MINEMET
3	Ecluse rotative	Devance Industries
4	Vibrant	AEG
5	Qualminos	MINEMET
6	Ventilateur	Delta neu
7	Transport pneumatique	PFAFF
8	Transport pneumatique	PFAFF
9	Mapp x	Phillips
10	Dépoussiérage	PFAFF
11	Perl x -2-	Philips
12	Refroidisseur SCU 4E	F&R Cooling Ltd.
13	Spectromètre	Philips
14	Argon Méthane	Alphagaz
15	Récupération farine	PFAF

The following features deserve comment:

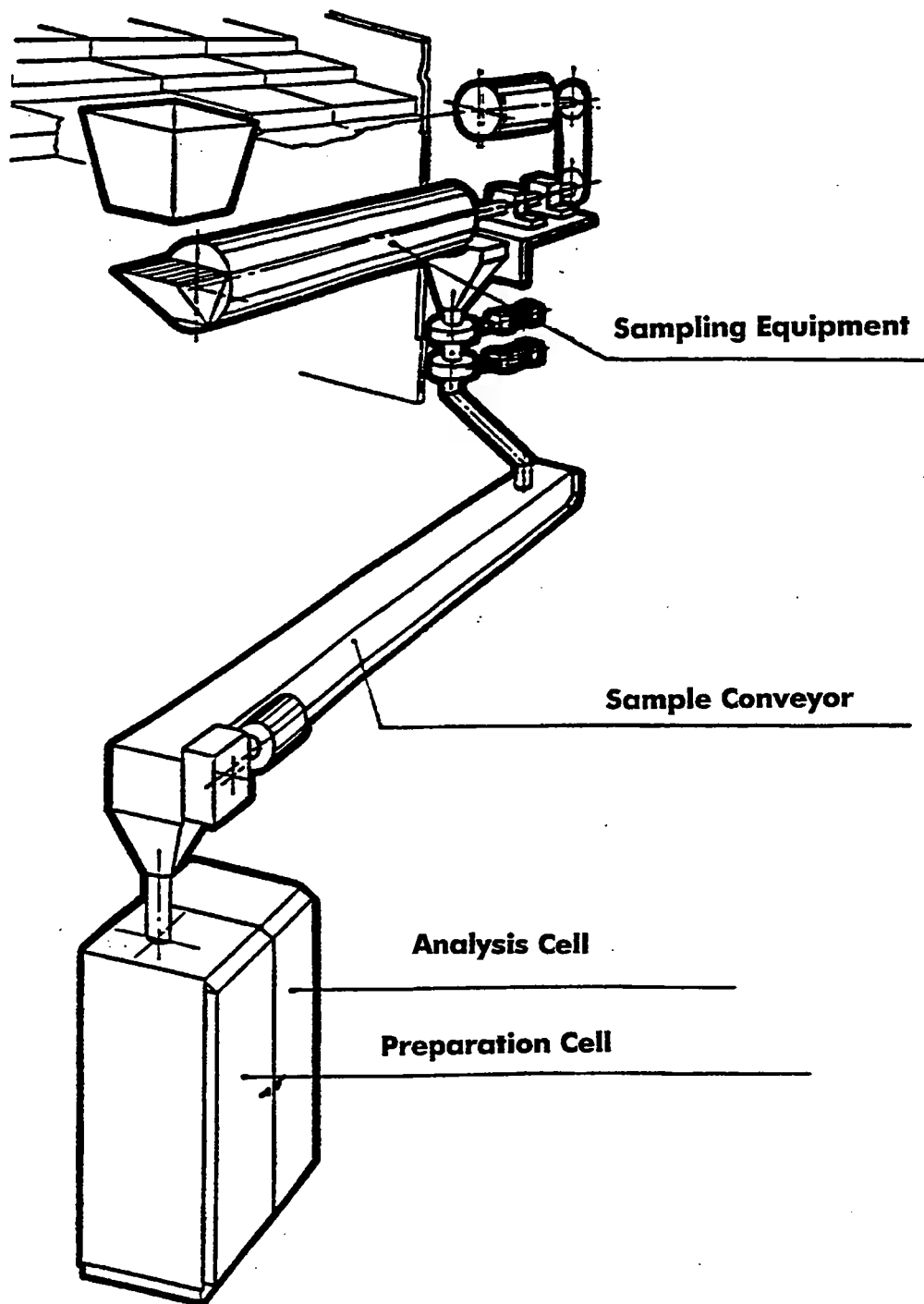
- ◆ Application of a robot for sample manipulation (MAPP'X):
Although in this application the task of the robot is limited to control the weighing of sample and fusing agent, the principal advantage of laboratory robots is seen in their flexibility to be programmable for a wide range of conventional laboratory equipment, equipment which can also be manually operated.
- ◆ Application of a low-power (200 W) XRF-spectrometer PW1660.
In contrast to previous instruments, the performance of the latest generation of low-power XRF-spectrometers (PW 1660, Oxford QX) appears to be quite satisfactory, unless special emphasis is laid on the speed of analysis and on analysis of heavy or very light elements.

3.2 Clinker Control

3.2.1 Conductometric free lime determination

Automatic free lime analysers, particularly designed for installation outside the laboratory, e.g. close to the clinker cooler, are offered by two suppliers in France, namely ISYS and ITECA. The layout is shown in Figure 10.

Fig. 10 **ITECA Free Lime Analyzer.**



In a usual arrangement, clinker samples are taken underneath the cooler grate. Free lime is determined by extraction of the ground clinker with ethylene glycol and measurement of the resulting conductivity of the solution. The results are transmitted to the central control room or laboratory.

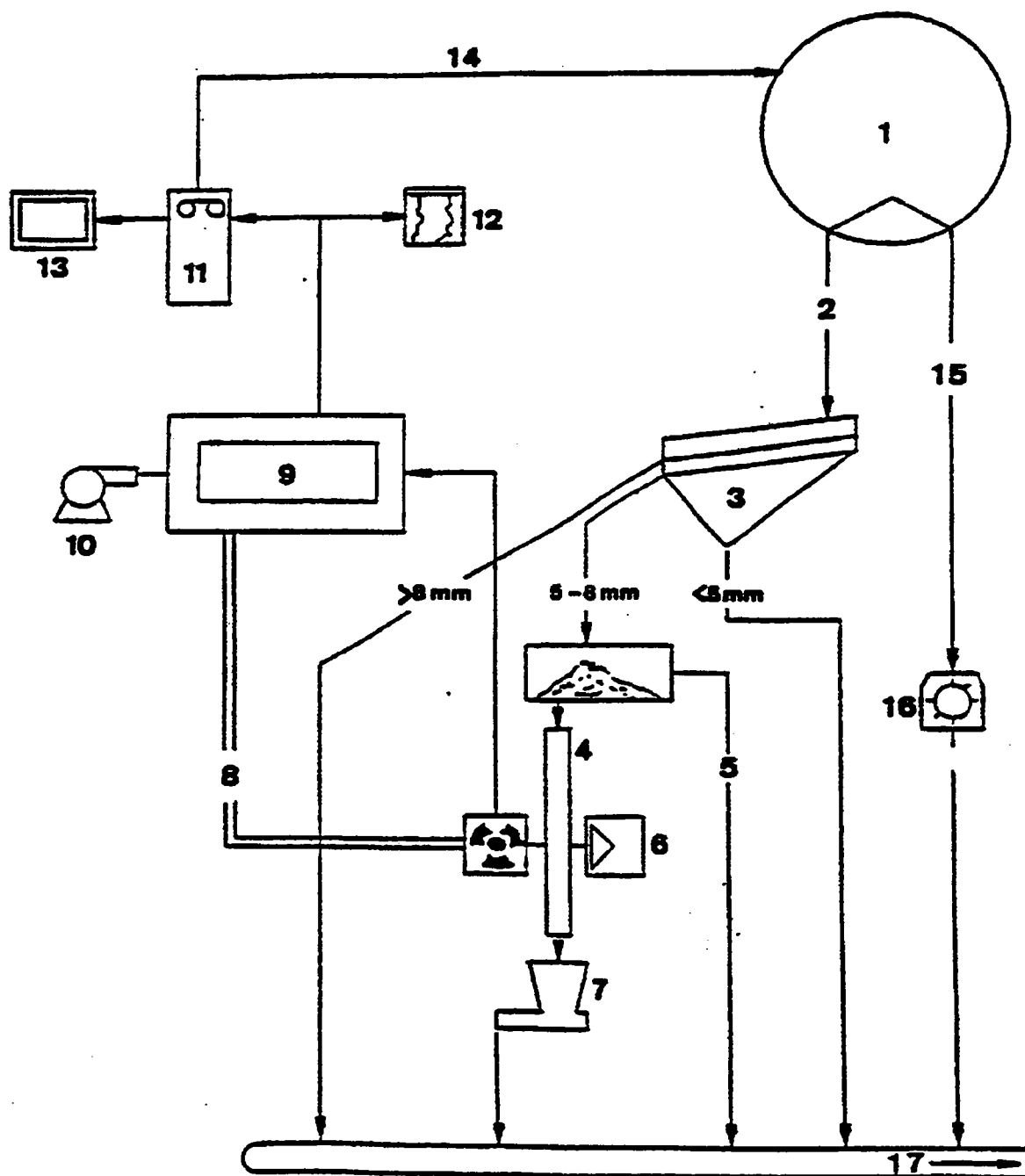
Such systems are, with good experience, fairly widely applied in French and Belgium plants, including the plants of Ciments d'Origny and Ciments d'Obourg (Lit. 3).

3.2.2 Automatic litre weight determination

At the Eclepens plant of the 'Societe de Ciments et Betons', Switzerland, the manual litre weight determination has successfully been replaced by an automatic on-line system, measuring the apparent clinker density with a nuclear densitometer (Lit. 4). The system is schematically shown in the next section -Figure 11a, along with the correlation of automatic and manual litre-weight measurement (Fig. 11b).

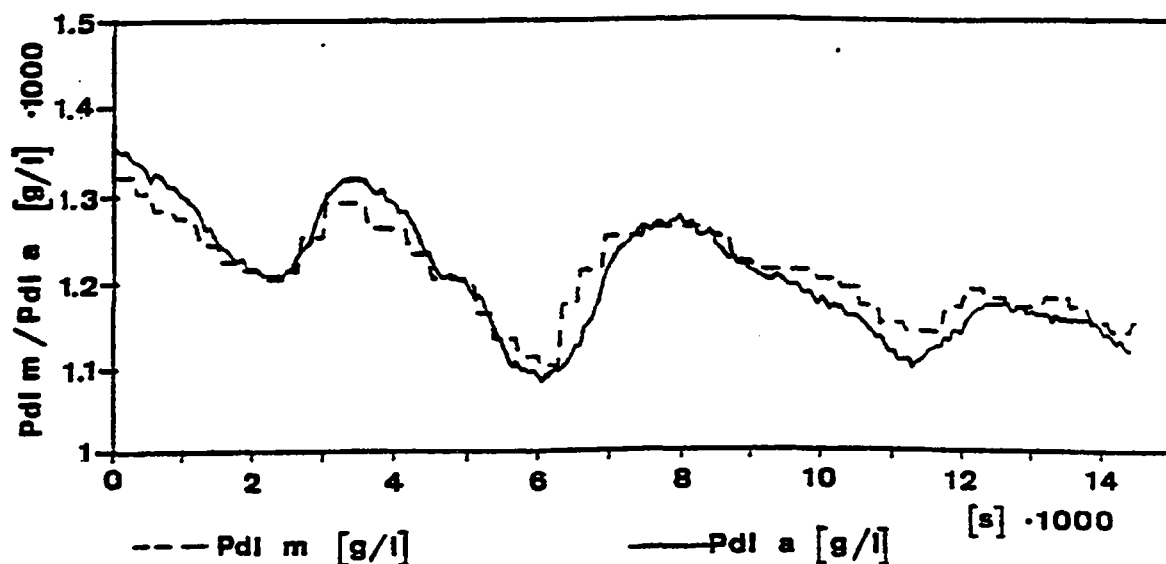
3.2.3 On-line Litre-weight Determination of Eclepens

Fig. 11a Circuit diagram for continuous measurement of the apparent density of clinker.



- 1) Kiln
- 2) clinker from grate
- 3) vibrating screen
- 4) measuring cell
- 5) overflow
- 6) gamma-ray source
- 7) variable vibrating funnel
- 8) cooling system
- 9) measuring electronics
- 10) cooling fan
- 11) process computer
- 12) analogue recorder
- 13) monitor screen
- 14) kiln control
- 15) clinker silo
- 16) clinker crusher
- 17) clinker to silo

Fig. 11b **Development of manual and automatic measurements of density over a period of 4 hours.**



It is worth noting that the density measurement is used as the primary set-point parameter for the automated kiln control system.

3.3 Physical Cement Testing

Automated, computer controlled equipment for physical cement testing has been available on the market for several years, in particular from the German company RK TONI TECHNIK. Such equipment comprises individual testing instruments up to integrated testing systems for mortar preparation, VICAT-testing, specimen storage and strength determination. A comprehensive review is given in Lit. 5.

While automated testing instruments such as Blaine-meter, laser granulometer, VICAT-testing apparatus, penetrometer etc. are frequently used in plant laboratories, integrated testing systems are not often applied we are presently not aware of any such installation in 'Holderbank' Group plants. It would appear that the potential for rationalisation and cost-savings is too small with the usual testing frequency in plant laboratories.

4. BULK MATERIAL CONTROL BY NEUTRON ACTIVATION ANALYSIS

The technique of prompt gamma neutron activation analysis (PGNAA) has already existed for a few years for on-line analysis of bulk materials. ~ Commercial equipment is presently available from Gamma Metrics, USA.

The principle of the method, and some characteristics relevant to its application are summarised in Figure 12 to 15.

Fig. 12a How Activation Analysis Works.

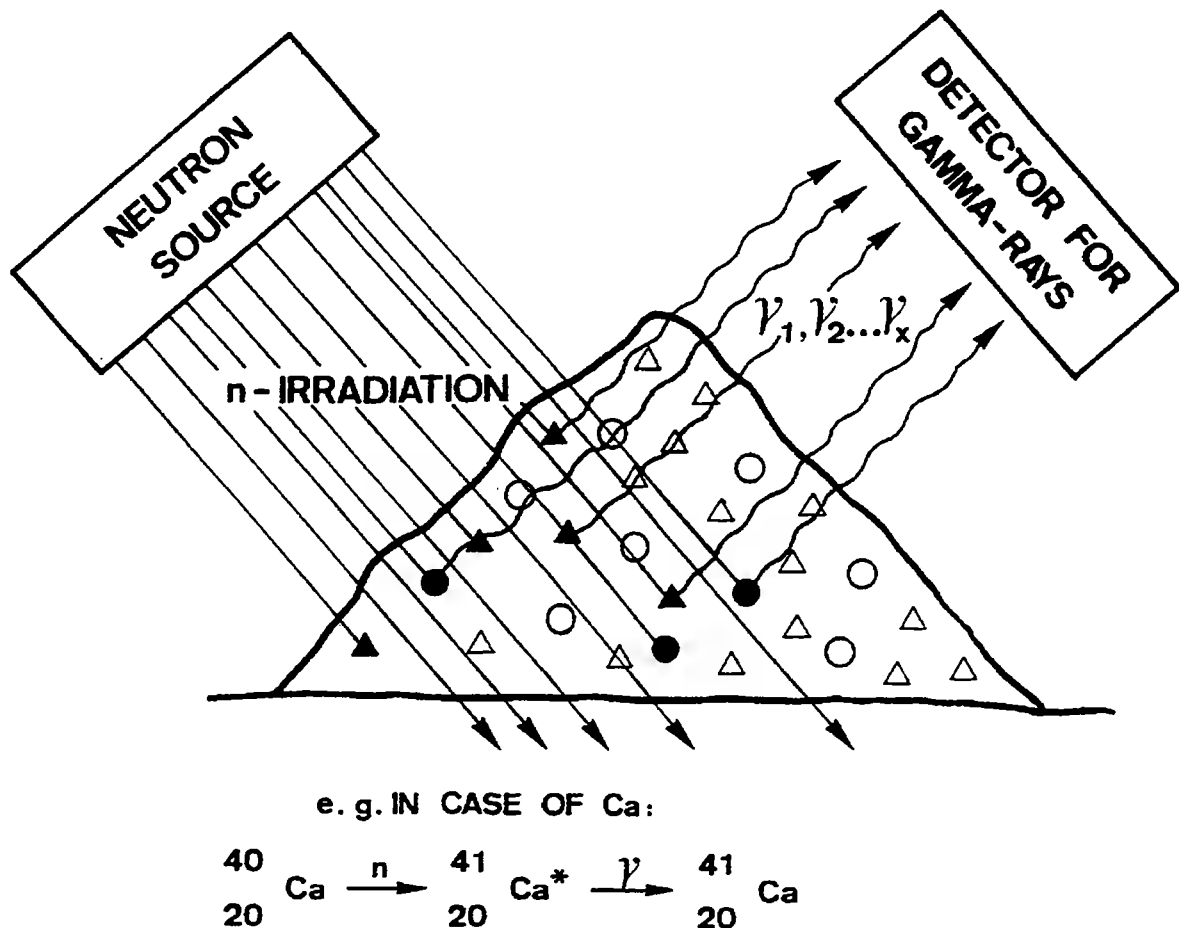


Fig. 12b Principles of Operation.

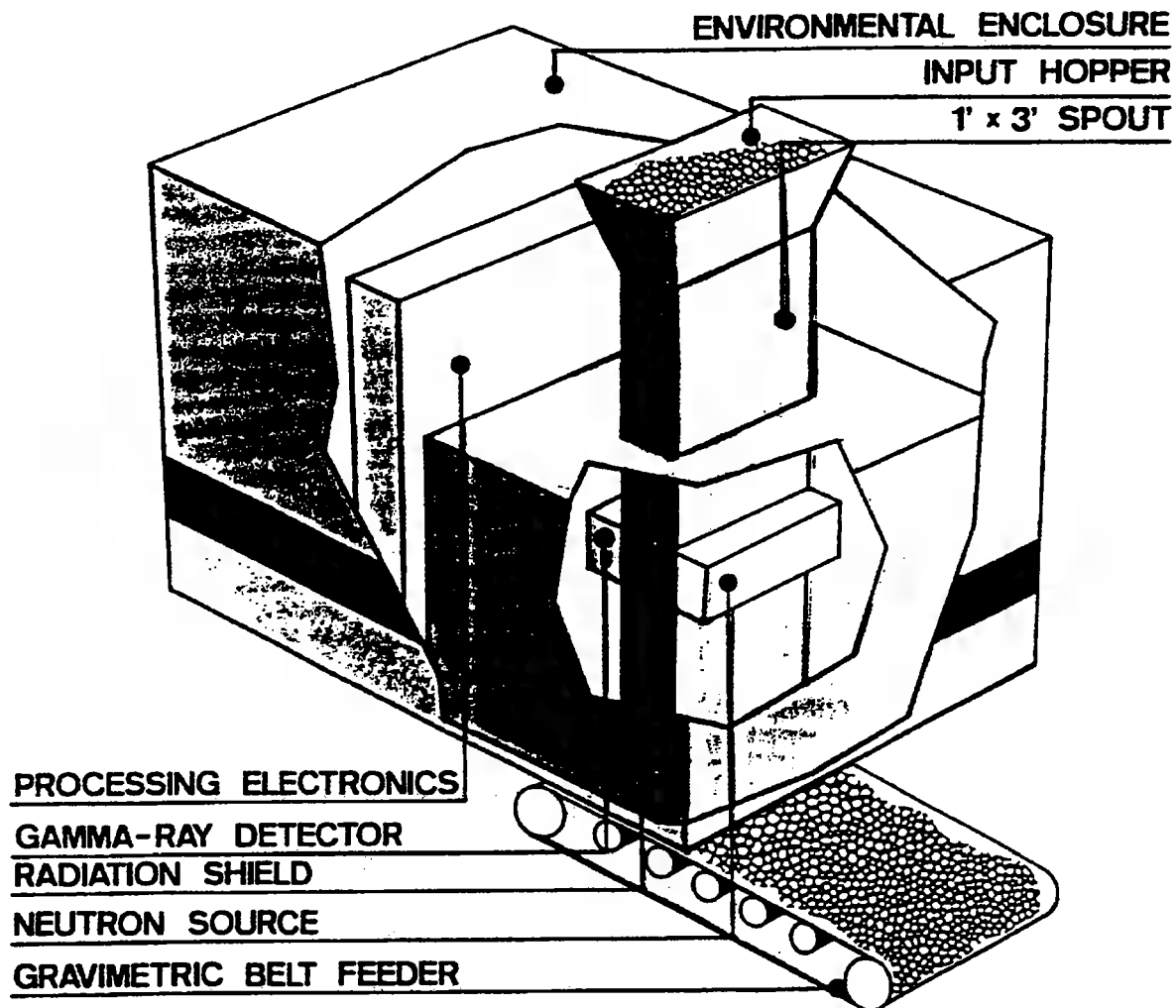


Fig. 13 PROMPT GAMMA NEUTRON ACTIVATION ANALYSIS (PGNAA)

Application:

- ◆ On-stream analysis of crushed raw materials or coal
- ◆ Blending control upon filling of integrated pre-blending bins
- ◆ Blending control on feed to raw mill
- ◆ Blending control on raw meal

Fig. 14 PROMPT GAMMA NEUTRON ACTIVATION ANALYSIS (PGNAA)

Advantages;

- ◆ Analysis on entire material stream maximum 1000 t/h
- ◆ Analysis on crushed material Ømaximum 100 mm
- ◆ Continuous, real-time analyses
- ◆ Multi-element analysis, incl. moisture
- ◆ Permits rapid reactions in control loops
- ◆ Low maintenance requirements
- ◆ High availability

Fig. 15 PROMPT GAMMA NEUTRON ACTIVATION ANALYSIS (PGNAA)

Disadvantages:

- ◆ High investment costs, excluding installations for material transport
- ◆ High service costs
- ◆ Problematic material flow with moist and sticky materials
- ◆ Relatively high threshold concentrations for certain elements (Na₂O, K₂O, MgO)
- ◆ Low precision at short measuring times
- ◆ Subject to regulations regarding handling of radioactive sources

Apart from the Phoenix plant in USA, the longest experience with such equipment has been made at the cement plant of the 'Compagnie des Ciments Belge', in Belgium, where it is installed ahead of the raw mill for raw mix blending control. The experience is apparently very satisfactory, both in achieving a uniform raw meal and a very high systems availability (Lit. 6).

Nevertheless, the still limited industrial experience does not yet permit a definite assessment of the potential and restrictions of the PGNAA application in the cement industry. A thorough assessment for each individual project is, therefore, still necessary.

In the context of assessing the PGNA-analyser for the pre-blending bed control at the future Norte plant of Cementos Apasco, Mexico, HMC has carried out analyser tests with six different plant specific raw material samples at the Gamma Metrics premises.

The tests revealed that:

- ◆ a linear calibration is possible over a wide range of concentration (Figure 16a)
- ◆ the standard deviation of repeated measurements is - as expected rather poor (Figure 16b)
- ◆ the analytical results are not affected by the water content of the material.

As a first conclusion, the analyser is considered to be suitable for the control of the filling of pre-blending beds. On the other hand the consequences of the high scatter of short-term analysis for the application in raw mill control - especially with raw components of fluctuating composition - need to be further clarified.

Fig. 16a Calibration of SiO_2 with PGNAA

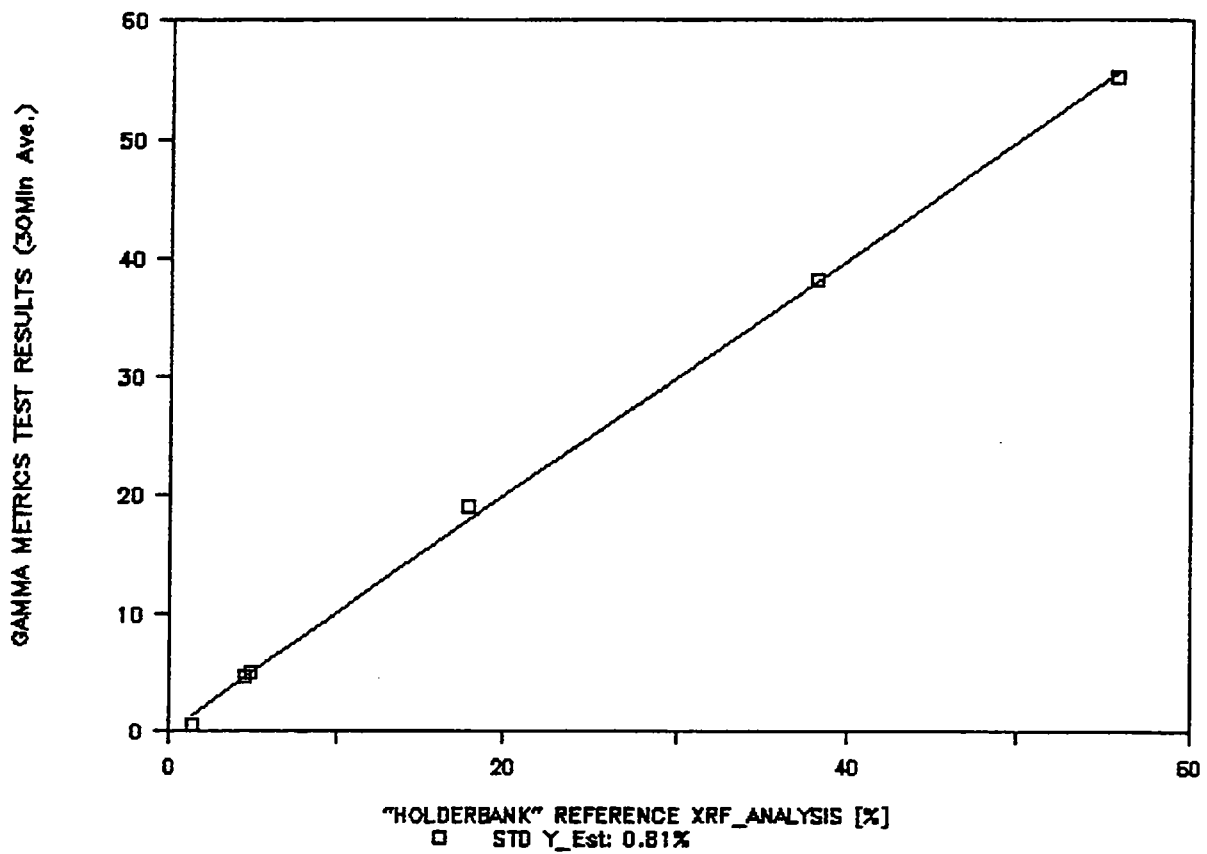
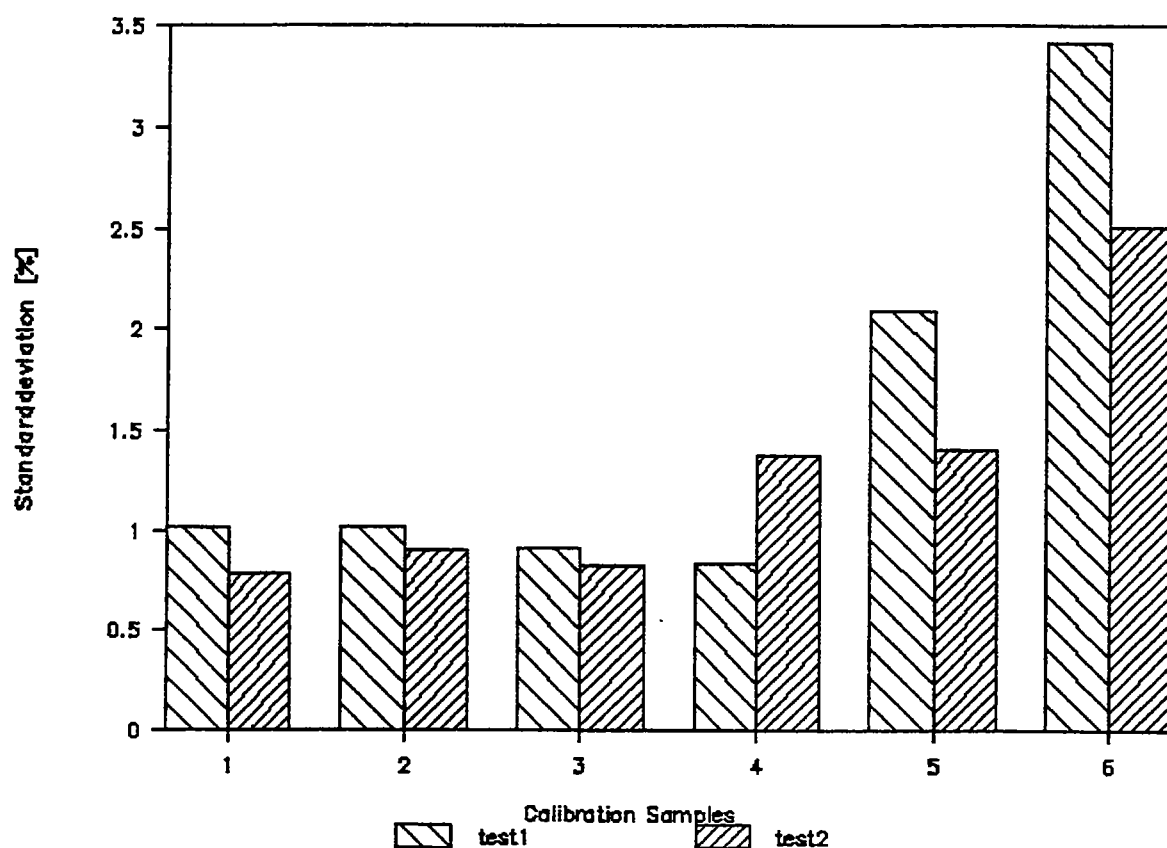


Fig. 16b PGNAA Reproducibility of SiO₂



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